DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES, 1923

REPORT OF THE DIVISION OF SCIENTIFIC INQUIRY FOR THE FISCAL YEAR 1923

By WILLIS H. RICH
Assistant in Charge of Scientific Inquiry
(With the collaboration of investigators)

APPENDIX VII TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1923

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INTRODUCTION.

The work of the division of scientific inquiry consists primarily in the investigation of the biology of those species of fish and shellfish that form the basis of the fishery industries. In common with much scientific work the service of this division is, in the main, one step removed from direct contact with the business man. The biological

[1] Appendix VII to the Report of the U. S. Commissioner of Fisheries for 1923. B. F. Doc. No. 956.

facts pertaining to the fisheries, which are discovered through scientific investigation, are essential for the reason that adequate measures of conservation must be based on a knowledge of the biology of the fish. The actual administration of measures of conservation, however, devolves upon other governmental and State agencies, and it is these agencies that directly perform the very necessary service of conserving the various fishery resources. Without scientific investigation, however, this direct service could not be properly conducted.

The utilization of the fishery resources of the United States has gradually increased since the Colonies were first established, and the past decade or two has witnessed a remarkable growth in many of our fishery industries. Certain fishery resources have shown more or less marked signs of depletion for years; more of these resources are showing evidences of depletion each year; and, with the increased exploitation, which we can observe and which will in all probability continue, we can only look forward to the depletion of resources at present apparently unaffected and to the more serious affection of those already showing evidences of depletion. Such exhaustion does not necessarily become obvious to everyone while the process is going on, and it is only through careful scientific investigation that it may be determined before it has reached a dangerous stage. The work to be done is of a distinctly practical nature, but must be interpreted and conducted by means of biological and oceanographical knowledge. Such investigations were never so essential to the preservation of our fishery resources as they are to-day.

The depletion of a fishery resource is not always the result of overfishing, although this usually is an important factor and in some instances apparently is the only one. Other factors of greater or less importance are the pollution of coastal and inland waters and the obstruction of streams by dams or other similar structures. Without regulation it is to be expected that the amount of pollution and the number of dams will tend to increase along with our increasing population and industrialization. Efforts to combat the various factors tending to deplete a fishery resource have been confined mainly to artificial propagation and to various legal restrictions affecting the seasons in which, and the means whereby, the fish may be taken, the discharge or treatment of pollutants, and the construction of fishways over dams or of screens in irrigation ditches.

It is the primary function of the division of scientific inquiry to determine, if possible, when depletion is taking place—or, still better, to determine when the condition of a fishery resource is such that depletion is likely to occur—and then to devise and propose means whereby such depletion may be prevented. Both of these are biological problems and, to be adequately solved, require a reasonably complete knowledge of the biology of the species in question. The more complete our biological information, the more perfect can be made the work of artificial propagation, and the better may the legal regulations be adjusted to the normal life of the various species of fishes so as to permit of the fullest possible exploitation of the resource without endangering the continuation of the supply.

It is with these things in mind that the scientific activities of the bureau are being directed more and more into studies pertaining to the biology, or life history, of the various fish and shellfish of com-

mercial importance. In years past the bureau has sponsored much scientific work of the highest order but not bearing directly upon problems connected with the conservation of our important fisheries. Valuable as this work in "pure science" is, it is felt at the present time, and in view of the limited funds available, that precedence must be given to investigations relating to fishes of economic importance. Happily, these practical investigations yield a considerable measure of results of interest and value from the viewpoint of "pure science," just as research in "pure science" has so frequently an ultimate, though often unexpected, practical application.

The general plans for the scientific investigation of our fisheries are being made on as broad a foundation as possible. The fundamental problem is to determine the factors affecting the abundance of any given species. One of the most important of these factors obviously is the abundance of food. The food of all fish and shellfish is, either directly or indirectly, those minute forms of animals and plants found floating in both fresh and salt waters and collectively known as plankton. The abundance of plankton, however, is directly determined by various physical factors, such as temperature, light, salinity, etc., and in the ocean the abundance of both fish and plankton in any given locality is dependent in great measure upon the oceanic currents in which drift the plankton and the eggs and young of many fishes. It is evident that the abundance of fish is determined to a considerable extent by various physical factors acting, in part indirectly, through the medium of the plankton. A comprehensive plan for the biological investigation of the fisheries must therefore include a study of these physical conditions, a study of the plankton, and finally a study of the fish and fisheries themselves. By this means we may hope eventually to understand the ultimate and proximal causes of fluctuations in the abundance of any given species, and this is the end of practical importance for which economic fishery investigations should be designed. All of these lines of inquiry are being given consideration, although emphasis is naturally placed on those investigations dealing most immediately with the fishes.

During the past year many important investigations heretofore begun were continued and some new ones were inaugurated. Outlines of the various studies that have been conducted will be found in the following pages.

The division has suffered a serious loss through the resignation of Dr. R. E. Coker, who had been in charge of the division since 1915. Doctor Coker had been connected with the bureau since 1902 and was thoroughly familiar with the various problems pertaining to the fisheries. The administration of the division has been aided greatly during the year by the advice and help that he has freely given.

INVESTIGATIONS OF FISH AND FISHERIES.

ATLANTIC COAST.

FISHES OF THE GULF OF MAINE.

For a number of years the bureau, in cooperation with the Museum of Comparative Zoology of Harvard University, has been conducting an oceanographic and biological survey of the Gulf of Maine.

Special attention has been given to the fishes and the floating plants and animals (plankton) that compose the food of the fishes, as well as to the physical and chemical condition and the circulation of the waters of the gulf. Several reports on special phases of the survey have been published, but not until recently did the body of data warrant undertaking a general account of the fish fauna. During the past year such an account has been completed by Dr. H. B. Bigelow and is now in course of publication.

The aim has been to prepare a handbook for the ready identification of the fish occurring in the Gulf of Maine, and to present a concise statement of what is known of the distribution of each, their relative abundance, and the more significant facts in their life histories. The descriptions have been made as simple as is compatible with scientific accuracy, and are limited chiefly to such external features as may suffice for identification in the field. As a further aid to identification, keys to all species have been provided. The area covered by the report includes the oceanic bight from Nantucket and Cape Cod on the west to Cape Sable on the east, thus including the shore lines of northern Massachusetts, New Hampshire, Maine, and parts of New Brunswick and Nova Scotia. The Gulf of Maine has a natural seaward rim formed by Nantucket Shoals, Georges Bank, and Browns Bank, but the 150-fathom contour has been taken as an arbitrary boundary because this includes all the species apt to be caught by commercial fishermen.

STUDIES IN FISH MIGRATIONS—TAGGING OPERATIONS.

As a part of a plan to investigate the biology of the important food fishes of the cod family (Gadidæ), an extensive experiment in tagging these fishes off the coast of New England had been inaugurated. The tagging is intended primarily to throw light on the movements of the various species of fish between the different fishing banks and between the banks and the shore. The bureau's steamer *Halcyon* is being used for this work and has been outfitted with appropriate fishing gear. The vessel left Gloucester for the first tagging cruise on the 16th of April and the first tags were attached on Nantucket Shoals. By June 30, 2,396 fish had been tagged. It is planned to attach a total of not less than 10,000 tags during the season. Cod, pollock, and haddock have been tagged, but by far the greater number has been cod. Some few returns have been obtained, but at this early date not even tentative conclusions can be given. The work has been conducted mainly by William C. Schroeder, with the advice and aid of Dr. H. B. Bigelow and Willis H. Rich.

The tags used are small and made of a noncorrosive metal so that they will withstand the action of sea water, as it is expected that returns will be obtained over a number of years. Each tag bears a serial number and the initials U. S. B. F. As the fish are caught a tag is attached, a record is made of its length, and the fish is then released. A reward of 25 cents is being offered for each tag returned, together with information as to when and where it was obtained.

In addition to the tagging experiment there are being collected material and data that will be used in other phases of the study of the fishes, such as the rate of growth, spawning habits, and age at maturity.

CHESAPEAKE BAY.

Work on a report on the fish and fisheries of Chesapeake Bay has been continued during the year by S. F. Hildebrand and W. C. Schroeder. Gratifying progress has been made. A large collection of fishes is on hand, and much of it has been worked over and identifications made. Many of the more important species are represented by large series of specimens, and from these considerable information is being derived as to the life histories, rate of growth, etc. Important data bearing on the extent and nature of the commercial fisheries have been collected and are being put into shape suitable for publication.

SALMONIDÆ AND SMELTS.

In the fall of 1922 work on the completion of important studies on the Salmonidæ and smelts of the Atlantic coast and coastal fresh waters was undertaken by Dr. William C. Kendall, a former assistant of the bureau. The greater part of this work involved the assembling and arranging of notes and the study and tabulation of data of several years' accumulation. Most of the time was devoted to the smelt problem, with the result that work on it is somewhat further advanced than that on the Salmonidæ. The question of the relationship of trouts (Salmonidæ) was also taken up from time to time. The problem is a complicated one and requires careful examination of many specimens from various localities and the tabulation of statistical measurements and counts. The studies so far indicate that many of the supposed rainbow trout of the Northwestern States are steelheads.

The smelts of the region referred to for years have afforded, and still afford locally, a valuable fishery in themselves as well as a valuable food supply for other important fishes, but they are suffering gradual depletion. These studies have been undertaken with a view to developing information that may be utilized in the conservation of the species. In a popular account that has been completed during the past year regard has been given to geographical distribution, habits, breeding, food, rate of growth, sizes attained, mortality, enemies, history of the fisheries, methods of the fisheries (both commercial and angling), and to legislation and protection. A more technical account has been begun. To throw light on the life history of the smelts, the scales are being studied and many proportional measurements made to determine the relationship between the marine and fresh-water forms. The relationship of the fresh-water smelts from various localities has also been given consideration, and studies of their evolution, embryology, and anatomy, and classification as to families, genera, and species, have been made.

LARVAL FISHES OF THE WOODS HOLE REGION.

A study of the larval fishes of the Woods Hole region has been begun by Marie D. P. Fish, and a considerable quantity of interesting material has been collected. The study of larval fishes has been greatly neglected, very little information on the subject being available. With the increased attention that is being given to biological studies of the various fishes, this sort of knowledge becomes of increasing importance. Attention is being devoted to the collection

and classification of larval fishes and also to certain features in their life history, especially their food and feeding habits, distribution, and growth. A large collection made over a number of years by the late Vinal N. Edwards is available for study. The seasonal variation in abundance of 36 species has been studied during the year.

FISHES OF KEY WEST.

At the Key West station Isaac Ginsberg, the director, made an effort further to build up the collection of a representative series of fishes of that vicinity that was started several years ago. Many specimens were added to the collection and progress was made in the identification and labeling of the specimens. Data concerning the occurrence, seasonal distribution, and abundance of the local fishes also were collected.

INTERNATIONAL COMMITTEE ON MARINE FISHERY INVESTIGATIONS.

Two meetings were held during the year—the first in Washington on November 10, 1922, and the second in Toronto on May 4, 1923. It is gratifying to record that at the second meeting the newly elected member from France was present. The purpose of the committee is to secure coordination of the various investigations pertaining to marine fisheries conducted by the several member countries. Among the more important topics discussed are the following:

Statistics of the deep-sea fisheries.—Information was given to the effect that the collection of the Canadian statistics is becoming more thorough. In the opinion of the committee it is desirable that each country represented should publish an annual statement of the total yield of the bank fisheries of the western Atlantic, and that the representatives of the several countries undertake to exchange the data for such annual statement.

Tagging of fish.—Interest was expressed by the committee in the tagging of codfish, pollock, and haddock, which is being undertaken by the bureau on the banks off the coast of New England.

Drift bottle experiments.—It was reported that a preliminary statement covering the more important results of the experiments of 1922 had been prepared and that the account in its final form would be furnished the various countries represented for publication if desired. A plan for the season of 1923 was presented, which involved the putting out of drift bottles along 14 lines covering the coast from the Strait of Belle Isle to Vineyard Sound.

Oceanographic investigations by the ice patrol service.—Appreciation was expressed of the work accomplished by the ice patrol service. In the opinion of the committee this work should be extended considerably in the future.

Mackerel investigation.—The committee went on record as considering it most desirable in the near future to initiate a comprehensive investigation of the mackerel.

At the close of the year the committee consisted of the following members: For Newfoundland, D. James Davies; for France, E. LeDanois; for Canada, W. A. Found, Dr. J. P. McMurrich, and Dr. A. S. Huntsman; for the United States, Dr. H. F. Moore, Dr. H. B. Bigelow, and W. H. Rich.

INTERIOR WATERS.

COREGONINÆ OF THE GREAT LAKES.

The investigations on the Coregoninæ, or whitefishes, of the Great Lakes have been continued; the field work was completed early in the fiscal year, and the attention of the investigators has for some months been directed toward the examination and comparison of collections and the compilation of data to be included in the final report. Dr. Walter Koelz is engaged in work on the systematic relations and natural history of the various species, while John Van Oosten is working on age determinations from the scales, the rate of growth, and allied problems. The problems involved in this investigation are difficult and will require considerable time for solution, but the progress made is regarded as most encouraging.

The studies on the systematic relationships and natural history of the Coregoninæ were continued on Lake Superior and Lake Nipigon. In Lake Superior an additional form was discovered and data on the distribution of the coregonine fauna in the eastern section of the lake were collected. In Lake Nipigon seven species were found, all but one of them with representatives in the Great Lakes, and some ecological data were secured. The preparation of the report on the whitefishes and lake herrings of the Great Lakes is well advanced.

Much additional material pertaining to the study of the life histories has been collected and our knowledge of the species materially advanced. Important information as to rate of growth, age at sexual maturity, average length of life, maximum age attained, and average length and weight at any year have been obtained. Where possible the variations in rate of growth in different localities are noted with a view to the planting of fry from hatcheries to the greatest advantage.

By obtaining two large representative collections of the lake herring taken from the same locality at the same season of different years, it has been possible to answer with confidence certain critical questions relative to the scale method of age determination as applied to the whitefish.

During the year a report on experiments carried out on whitefish of known age and life history was completed and is now in press. This report presents evidence to show that the correspondence between the known age of the fish and the number of annuli, or yearly rings, observed on the scales is exact and holds for old fish as well as for the young.

Much aid has been given to these investigations by the University of Michigan, particularly by Dr. Jacob Reighard, and also by the State department of conservation. A fine spirit of cooperation is manifested, which will materially aid and advance the work.

MISSISSIPPI RIVER FISHES.

The investigation of the fishes of the Mississippi Basin has been continued by members of the scientific staff at the Fairport laboratory under supervision of the director, R. L. Barney. The work has been confined largely to the hackleback sturgeon, rock sturgeon, and sheepshead. A considerable amount of material on the growth, food, sexual cycle, habits, etc., of both the rock and hackleback

sturgeons has been collected. There is evidence in both of these species that sexual maturity is not reached as early as in the case of the "scaled" fishes, and that, unlike these fishes, the reproductive cycle is not an annual one. If these observations are corroborated by future work it will explain to a considerable extent the ease with which the sturgeon fishery has been depleted. A large collection of dermal plates of both species of sturgeon has been made, together with data on weight, length, and the condition of the sex organs.

The study of the natural history of the sheepshead has included observations on their habits in Lake Pokegama, Minn., and the collection of otoliths and scales (to be used in age determination), with records of length, weight, and sexual condition. These data have been supplemented by other data of similar character obtained from fishes taken at Fairport, Iowa.

Some observations have been made on the habits and natural history of the channel catfish.

Tagging experiments have been conducted at several localities in the Mississippi Basin for the purpose of obtaining information as to the migrations of several of the more important fishes. Over 150 small hackleback sturgeon were tagged and liberated in the Mississippi River. A great many sheepshead were tagged and liberated at Lake Pokegama and at Fairport, Iowa. In cooperation with the Louisiana State Conservation Commission some 300 small paddlefish were tagged at Lucas, La. These fish were seined from a large borrow pit outside the river levee, tagged, and transported to the river. The fish were all of small size, presumably of the year, none being longer than 12 inches. In Lake Pepin, a wide section of the Mississippi River between Minnesota and Wisconsin, 1,660 fish were tagged and liberated. These tagged fish were distributed among the various species as follows: Wall-eyed pike, 728; saugers, 771; sheepshead, 16; carp, 42; buffalo, 103. At the close of the fiscal year comparatively few of the tagged fish had been recovered and no significant results had been obtained. It is hoped and expected that future returns will be sufficient to give the information desired.

DESTRUCTION OF TROUT BY PELICANS IN YELLOWSTONE NATIONAL PARK.

During the summer of 1922 the bureau, in cooperation with the National Park Service, began an investigation of the pelicans in the Yellowstone National Park to determine their destructiveness in relation to the trout, the supply of which the bureau helps to maintain by artificial propagation. The services of Dr. H. B. Ward, of the University of Illinois, were secured for this work. The results of this investigation indicate that the pelican is a highly specialized predatory bird, and that its breeding period in the park is so precisely synchronized with that of the trout that its depredations effect maximum losses.

The pelican colony on Yellowstone Lake in 1922 was found to number between 500 and 600 birds, from which about 200 young resulted. For the six weeks of their sojourn on the lake they subsist almost entirely upon the black-spotted trout, the toll taken by each pelican during the season amounting to about 350 fish, and in-

volving, besides, a large loss in trout eggs through the destruction of the breeding fish.

The pelican represents a strange and interesting ancient type of bird life and it is not desired to exterminate it in the Yellowstone Park, where it is of much interest to tourists. Measures have been recommended, however, for the regulation of its numbers through the destruction, by proper authorities, of a percentage of the eggs deposited on the breeding grounds in the park. The recommendations are now under consideration by the Bureau of Fisheries and the National Park Service.

It was originally suggested that attention be directed rather definitely to the problem presented by the parasites of the pelicans and of the trout in Yellowstone Lake. Some data were secured on this point, but the general problem of the destructiveness of the birds with respect to the trout was considered to be of such immediate importance that the question of parasites was temporarily relegated to the background and was not made the subject of special attention.

PACIFIC COAST AND ALASKA.

ALASKA SALMON.

Especial attention was given during the summer and fall of 1922 to a study of the salmon in the Alaska Peninsula fisheries reservation. The work was conducted by Dr. C. H. Gilbert, of Stanford University, and Willis H. Rich, assisted by W. P. Studdert. During June and July 4,000 red salmon were tagged with numbered aluminum tags in an effort to learn something of their migrations. The results of this experiment were striking and gave information of the greatest value. A report was prepared by Doctor Gilbert and has been published.

The tags were attached at four localities near the end of the Alaska Peninsula, where several large canneries are located. Of the 4,000 tags attached, 861 were put on at Unga Island, 200 in Morzhovoi Bay, 2,300 in Ikatan Bay, and 639 in the vicinity of Port Moller. A total of 709, or 18 per cent, was reported recaptured either in the vicinity where tagged or at more distant points.

Of the 639 fish tagged near Port Moller 174 were recaptured, all of them close to the point where they had been liberated after tagging. It is evident that the Port Moller fishery is sustained largely, if not entirely, by local runs.

The general trend of the migration of the fish tagged in the vicinity of Unga Island was to the westward. Furthermore, they proceeded directly to Morzhovoi and Ikatan bays without entering on their way the minor red salmon streams to be found along the southern side of the peninsula. A few of these fish moved eastward along the south shore of the peninsula, one being captured at the mouth of the Ozernoi River and four on the eastern shore of Cook Inlet. Other captures were reported from Bristol Bay.

The results obtained in Ikatan and Morzhovoi Bays indicated an extensive movement of salmon back and forth between these two bays. A purely haphazard movement of the fish seemed to be indicated. It was made abundantly clear that Ikatan and Morzhovoi Bays form parts of the same fishing grounds and deal with the same

schools of fish, which pass back and forth from one to the other. No conclusive evidence was obtained, however, that any considerable proportion of the commercial run frequents either the local spawning grounds tributary to these bays or other local spawning grounds on the south side of the Alaska Peninsula.

A most important feature of the Ikatan, Morzhovoi, and Shumagin tagging experiments consisted in the considerable number of marked salmon that passed into Bering Sea and were recaptured in the Port Moller district and on the various fishing grounds of Bristol Bay, including those off the mouths of the Ugashik, Egegik, Naknek, Kvichak, and Nushagak Rivers. These amply demonstrate a movement throughout the season from the North Pacific into Bering Sea, and indicate that a considerable contingent of the red salmon that form the great run on the northern shores of the Alaska Peninsula have their feeding grounds in the North Pacific and enter Bering Sea only when on their final spawning migration. It is felt that this is one of the most important contributions ever made to our knowledge of the oceanic migrations of fishes.

The investigation of the salmon run in the Karluk River was continued. The count of red salmon entering the stream was much below that of 1921, and an investigation of the spawning ground made by Doctor Gilbert and Mr. Rich showed a corresponding scarcity of spawning fish.

SALMON OF PACIFIC COAST STATES.

Progress has been made in the investigation of the life histories of the salmon of the Pacific coast. Very satisfactory results were obtained during the year from one of the extensive salmon-marking experiments in progress on the Columbia River. During the spring of 1920 the bureau and the Oregon Fish Commission, in cooperation, marked 100,000 young sockeye salmon (*Oncorhynchus nerka*) at the Herman Creek hatchery of the Oregon commission. These fish were reared from eggs brought from the Yes Bay hatchery of the bureau in 1918 and had been hatched at the Bonneville hatchery of the Oregon commission and reared at the Herman Creek hatchery. The marking was under the supervision of Willis H. Rich, of the bureau, and consisted in the removal of the adipose and both of the ventral fins.

A considerable number of these fish, grown to maturity, were recovered this year in the Columbia River, and scales and data from approximately 1,200 were obtained by H. B. Holmes, temporary assistant. Mr. Holmes was greatly aided in this work by the Oregon Fish Commission, which offered a reward of $1 for the return of the scars from each fish accompanied by the necessary data and scales.

These returns are far the most satisfactory that have ever been obtained from the marking experiments that have been conducted on the Columbia River during the past six years. It is especially interesting that the results obtained this year are quite comparable with those obtained in 1918 from a similar experiment begun in 1916, and the estimated per cent of the total number of returned fish is very similar. The results this year further support those obtained in 1918 in that the adult fish were distinctly different from the typical Columbia River fish of the same species, locally known as

bluebacks, and resembled the parent fish of Yes Bay. This resemblance is not only external but involves also the quality of the flesh, that of the Yes Bay fish being inferior to that of the Columbia River blueback. This confirms the earlier conclusion that heredity is more important than environment in determining the general appearance and quality of the flesh of salmon.

An investigation of the spawning grounds of the blueback salmon of the Columbia River was made by Harlan B. Holmes during the fall of 1922.

Up to the present there have been no accurate data as to where this species of salmon now spawns in the Columbia Basin. All of the well-known areas formerly used have been rendered inaccessible by the construction of dams and irrigation ditches. Notable among these old spawning grounds are the large lakes of the Yakima Basin of Washington, the Payette Lakes of Idaho, and Wallowa Lake of Oregon, all of which are now closed to salmon. The especially large run of bluebacks in the Columbia River during the season of 1922 made this year a very favorable one for the study of the present spawning grounds. The results of the investigation show that a run of these fish passes up the Salmon River in Idaho at least as far as Sunbeam Dam, about 12 miles east of Stanley. The series of lakes known as the Red Fish Lakes are above this point and were visited for evidence of spawning fish. No direct evidence that the fish got above this dam was obtained, but it is not at all impossible that many of the fish were on their way to the spawning streams visited but at the time were in the lakes or at points in the river that were not visited. The evidence that there is still a run of bluebacks in the Red Fish Lakes seems sufficient to justify providing a certain passageway over the dam for the returning fish in future years. The present fishway over Sunbeam Dam is considered inefficient.

INVESTIGATIONS OF SHELLFISH AND TERRAPIN.

OYSTERS.

Investigations relating to oyster culture were conducted during the fiscal year by J. S. Gutsell and H. F. Prytherch, scientific assistants, aided during the summer months by J. G. Scott. Dr. P. S. Galtsoff also carried on some special oyster investigations. As in recent years, the "setting" problems of Long Island Sound and Great South Bay, Long Island, received chief attention.

In the summer of 1921 there had been an oyster "set" of exceeding abundance in Great South Bay. Before the summer was over it was nearly all dead. The work of that summer and fall and of the following spring showed that where the spat had attached well above the bottom, as on "pound" stakes and boat bottoms, good growth and no excessive mortality had occurred. The discovery that H_2S was being generated by decomposing organic material over a large part of the bottom seemed to account for the loss of bottom set and the survival of that which was elevated. It was hoped that in 1922 definite evidence might be obtained for or against this hypothesis and especially that the degree of elevation required for the survival of the set might be determined and a way opened for improvement in commercial practice to meet the special needs of this area. Unfor-

tunately, however, complete failure of the oyster set made it impractical to add to our knowledge in regard to the minimum or optimum elevation for growth and survival, but data of value for the determination of the correlation of temperature and oyster spawning and setting were obtained. Later, at Milford, Conn., it was found that the presence of very minute amounts of H_2S causes spat to stop feeding, and from this it follows that the presence of the gas is, at the very least, highly disadvantageous.

The work in the New Haven-Bridgeport area of Long Island Sound, where once an important supply of northern "seed" oysters was produced and where the sets have become alarmingly reduced, consisted in the collection of data regarding temperatures; spawning of oysters; the occurrence, distribution, and development of larvæ and spat; and the effects on spat of various chemicals known to be important pollutants. Data concerning the age and growth of spat also were collected. The investigations revealed the fact that the set of oysters was much above the average following a season in which the oysters in harbors and inshore areas of the Sound spawned comparatively early.

Oyster larvæ were found in the Housatonic River for the first time in the five seasons during which these investigations were carried on. For a number of years there had been no oysters in this river until a planting was made in the spring of 1922. The set was comparatively good, but a very large proportion was destroyed by starfish and drills, and to a considerable but uncertain extent by other adverse factors. The set of oysters at the mouth of the Housatonic River occurred during a time of lessened trade-waste pollution due to decreased manufacture and when water conditions presumably were temporarily much better than usual. Because it was believed that improved water conditions may have had a great influence on the set, it seemed desirable that a survey be made at this time for comparison with conditions obtaining during periods of greater industrial activity. In October, therefore, in cooperation with the Bureau of Chemistry, an investigation was made of water conditions in the Housatonic River and New Haven Harbor with regard to trade-waste pollution with heavy metals, and also with regard to oxygen content and alkalinity. From this work it appeared that conditions were chemically decidedly worse in the optically clean Housatonic River than in the obviously fouled New Haven Harbor. This was most notably true with regard to copper, but also held for zinc and dissolved oxygen.

In the experiments with pollutants a copper salt was found most destructive. A solution of copper chloride containing 10 parts per 1,000,000 of copper gave complete mortality of oyster spat under conditions in which other metallic salts gave less mortality and the control experiments nearly complete survival.

An inquiry into the relationship between spawning and water temperatures has been carried on for a number of years. At this stage of the investigation the evidence indicates that fairly satisfactory temperature conditions, viz, the attainment of 70° F., or higher, by late July or early August, and the maintenance of about this temperature for the few weeks required for spawning and setting, are generally to be expected not only in estuaries but also in inshore areas in the sound. Therefore, until conditions in the estuaries can be

greatly improved, in so far as pollution is concerned, the general planting of inshore lots with oysters (where this will not result in loss from storms, etc.) is to be urged as the most hopeful method in sight for the improvement of oyster sets in the sound.

In September there came to the attention of Dr. P. S. Galtsoff, in the course of his hydrographic surveys, the matter of the death of large numbers of "set," especially in the neighborhood of New Haven. He found that in addition to those being killed by the drill, many were dying from some unknown cause. Attempts, by histological methods, to connect this mortality with some parasite were unsuccessful. When, in October, he again visited this region he found that although the drill was still active the mortality from the unknown cause or causes had ceased.

CLAMS AND CRABS OF ALASKA.

In connection with the administration of fishery reservations in Alaska, an investigation of the clams and crabs has been undertaken. The utilization of these shellfish has only just begun in Alaska, and while there is no immediate danger of depletion it is desired to obtain all the information that may be needed later to properly control the utilization of the resource. For this work the bureau has obtained the services of Dr. F. W. Weymouth, of Stanford University, who has made extensive studies of the life histories of both clams and crabs in California and British Columbia. Some preliminary work has been done in the way of compiling information as to the present state of the industry and active field work will be begun soon after the close of the present fiscal year.

FRESH-WATER MUSSELS.

Investigations of the factors affecting the survival and growth of juvenile mussels conducted at Fairport and at Lake Pepin have been characterized by important results, which have appeared sufficiently favorable to warrant the establishment of a small rearing system at Fairport. This system consists of 140 metal troughs fed by a gravity supply of water, twice sedimented in ponds before reaching the troughs. The elasticity of this system, and its apparent efficiency, mark it as a distinct step toward the conservation of fresh-water mussels. One of the main features of the system is the exclusion of light from the troughs. Experiments have proved that the dark trough, probably because it simulates natural conditions on the bottom of mussel-bearing streams, will produce about 25 times as many mussels as the open trough.

Similar noteworthy results have been produced experimentally at Lake Pepin, Minn., by the use of a totally different apparatus. There a floating basket with wooden floor approximately 8 feet below the surface was used. A second smaller basket, in which the infected fish are held until the mussel embryos are liberated, was suspended within the larger inclosure. This style of pen and bottom was used in an effort to avoid losses caused by enemy organisms living on the lake bottom. Its value is evidenced this year by the fact that on the bottom of one experimental float 10 feet square more than 23,700 young mussels, all at least half an inch long, and many longer, were

recovered. These mussels spent their parasitic life on wall-eyed pike and saugers and represent an 84.6 per cent survival of the glochidia, constituting the total experimental infection. The production of these juveniles averaged 237 per square foot of bottom surface. The mortality of mussels after having reached this length is approximately nil.

The results of these experiments stand as an indication of the possible usefulness of controlled methods over the present method of artificial propagation in which infected fish are liberated in natural bodies of water to drop the juvenile mussels on bottoms, where it is unlikely that more than a 2 or 3 per cent survival results. These results are particularly significant if, based on the apparatus used, artificial mussel propagation may be carried on more effectively than formerly with results more tangible, cheaper, and less limited by natural physical, chemical, and biological factors.

During the year two undescribed parasites of fresh-water mussels, ciliates of the genus Conchophthirius have been observed. One of these has no particular significance as it is apparently harmless. The other, however, evidently is the cause of the mortality of large numbers of larval mussels while they are still held in the marsupia of the adults. Mussels seriously infected have been taken in Lake Pepin and from the ponds at Fairport.

Statistical and biological surveys of mussel beds have been carried on during the year at Lake Pepin and at Lake Pokegama, Minn. Artificial culture of mussels by the inoculation of the host fishes has been carried on for several years in both bodies of water. At Lake Pepin there has also been in operation for some time a five-year alternate sectional closure of the lake to commercial mussel fisheries. The surveys, therefore, especially in the case of Lake Pepin, have provided important data regarding the benefits derived from artificial mussel culture and the advantages to be expected from protective closure of streams. The survey of Lake Pepin indicates, though not conclusively, that the important commercial mucket (*Lampsilis luteola*) has increased in the lake. This apparently is due to the artificial culture of this species that has been carried on by the bureau since 1913. The noncommercial species and other commercial species that have not been propagated apparently have decreased during the same period of time.

The presence in the lake of a large number of mussels under 10 years old further corroborates the value of the work. The returns from this survey are the best indication of the value of artificial mussel culture so far obtained. The protective closure, as inaugurated in 1918 through the cooperation of the States of Minnesota and Wisconsin, is unquestionably a desirable aid in perpetuating the mussel fisheries of the country.

Physiological and anatomical studies of the mussel embryo and its development, and experimental efforts at metamorphosis induced without the normal stage of parasitism on fishes, were conducted by Dr. Edgar Allen at the fisheries biological station, Fairport, Iowa. Observations were made on a number of mussels, but particularly on the species *Anodonta imbecillis* and *Strophitus edentulus*.

Dr. L. B. Arey continued his investigations of (1) the history and structure of the normal cyst of fish tissue surrounding the mussel glochidium, its relations to the surrounding host tissues, mutual

adjustments, nutritive relations, etc.; (2) the morphological study of the glochidia of a large number of fresh-water mussels; (3) the nutrition of the encysted glochidium; and (4) the histological changes in tissues of the host due to an immunity reaction of the fish to inoculation with glochidia.

Dr. E. P. Churchill, jr., during the summer of 1922 was engaged in a continuation of his study of the food and feeding of fresh-water mussels. His attention was confined chiefly to feeding reactions and requirements of juvenile mussels.

Activities looking toward adequate protection for the commercial mussels in order that the industry might be perpetuated have been of a cooperative and advisory character. During the year, as a result of endeavors along this line, the fish and game authorities of the States of Minnesota, Iowa, Wisconsin, and Illinois have cooperated to close to commercial fishing for a period of five years alternate sections of the Mississippi River between Brownsville, Minn., and Keokuk, Iowa.

TERRAPIN.

A series of cultural and breeding experiments with the diamond-back terrapin was continued at Beaufort, N. C., by Charles Hatsel, the acting director of the station. Careful records were kept of the reactions obtained by varying methods of feeding, size of range, etc., and special experiments in selective breeding were begun. Further attention has been given to the determination of the cause or causes of a bacterial disease among young winter-fed terrapin and to methods of combating the disease.

Terrapin from a wild brood stock have been grown in confinement under various conditions for the purpose of determining the environment under which the best results may be obtained. It has been found that at least one year's growth can be gained by placing young terrapin in a hothouse, keeping them warm, and feeding them regularly for the first winter of their lives. Winter feeding for older terrapin has not proved to be of much value. The young that received this winter treatment the first year have also invariably reached sexual maturity and produced eggs one year earlier than those of the same age that were permitted to hibernate. Diseases among the winter-fed stock, however, are more prevalent than they are among the hibernating terrapins and constitute a problem that requires further study. Several experiments have been conducted in the past and others are now under way looking toward the successful control of these diseases. Fortunately, diseases among terrapin of one or more years of age are very rare.

The offspring of wild stock have been reared to sexual maturity in captivity in four years. Several lots of young, hatched from eggs laid by terrapins reared in the pounds at the Beaufort station, are now being held, and their rate of growth is compared from time to time with that of terrapins of the same age hatched from eggs of the wild brood stock. To date the rate of growth in the offspring of the "domestic" stock invariably has exceeded that of the "wild" stock, indicating that as early as the second generation after confinement these animals are becoming adapted to the changed environ-

ment. Certain lots have been separated for selective breeding. The terrapins in these lots were selected for rapid growth, size, and general healthy and vigorous appearance. The third generation of domestic terrapins probably will result during the next breeding season from this series of experiments. The results attained show beyond a doubt that it is entirely practical to grow diamond-back terrapins in confinement for commercial purposes, and, indeed, this appears to be the only hope of maintaining a supply of this animal, which is nearing extinction.

ECOLOGICAL AND OCEANOGRAPHIC STUDIES.

CONTROL OF MOSQUITOES BY MEANS OF FISH.

Investigations of fishes in relation to mosquito control were conducted at Augusta, Ga., during the mosquito-breeding season of 1922 by Samuel F. Hildebrand, ichthyologist, working in cooperation with the United States Public Health Service. Particular attention was devoted to a study of the relationship that various plants bear to mosquito control by the use of fish. A single plant—the duckweed Spirodela—was found to prevent mosquito production in a measure. All other plants used in the experiments appeared to favor mosquito breeding. The extent to which plants favored mosquito breeding and to what extent they formed "barriers" between the fish and the wiggle-tails was arrived at through the creation of fishless areas in ponds supporting various types of vegetation in which mosquitoes were permitted to breed unmolested for a time. Later such areas were restocked and the results were checked.

Extensive studies of sex ratios in Gambusia (the most important of the fishes used for mosquito control) were made, from which it was determined that the males are proportionately fewest in August, when among the specimens examined only 1 male occurred among about 8 females. In October the males had become much more numerous and the proportion was about 1 male to 2 females. The conclusion is that the male is the weaker sex, and in August, just before the early young of the season become sexually mature, so many of the males have died or have been destroyed by enemies that the disparity is very great. In October, when many of the young of the previous spring and summer have become sexually mature, the young males greatly increase the proportionate number of that sex. Microscopic studies of the sexual organs of a limited number of young fish showed a sex ratio of about 1 to 1.

It is well known that in the northern part of its range Gambusia spawns only during the summer, but it had previously been noticed that gravid females may be taken at Key West at all seasons of the year. Consequently the director of the Key West station, Mr. Ginsberg, was requested to confine females in the aquarium and make careful observations relative to the period and frequency of spawning. These observations show that at Key West Gambusia spawn the year round at more or less regular intervals of four weeks.

Extensive experiments relative to the proper handling of Gambusia in confinement and shipment were conducted. It was shown that a larger proportion of the fish survived when approximately 3 inches of water was placed in a vessel of a given diameter than if 8 to 10 inches of water were used in the same container.

During the year Mr. Hildebrand visited several localities in the South in an advisory capacity, offering suggestions for the best use of top minnows for the control of malaria and for the propagation of these fish for distribution.

OCEANOGRAPHIC WORK.

During the fiscal year 1923 laboratory work on the collections made in the hydrographic and biological survey of Chesapeake Bay was inaugurated, the field work in the main having been completed early in June, 1922. The special collections have been segregated and assigned for study by specialists in the National Museum and biologists in various parts of the United States and Canada, and a comprehensive report on the fish and fisheries of the region is well advanced. The data relating to the physical and chemical features have been compiled, and a report on this phase of the investigation is also well under way.

In this investigation the bureau has received cooperation and assistance from the United States Geological Survey in the determination of the salinities of the water, and from these results most of the densities have been calculated. The Geological Survey has also furnished important information concerning the average amount of fresh water that drains into Chesapeake Bay, and this, together with valuable information prepared by the United States Coast and Geodetic Survey as to the total area, areas of cross sections, and volume of sea water entering the bay, will have an important bearing on the study of the movements of the water and the organisms contained in the water. The United States Weather Bureau has cooperated by furnishing information on the daily precipitation during the last few years in drainage basins that feed Chesapeake Bay. These important data have been found very valuable in the study of the variations in position of the water layers of different density in the bay.

The survey of Chesapeake Bay was begun in 1912 by Lewis Radcliffe and William W. Welsh primarily for the study of the Clupeidæ. The work was later extended to include the general fauna and flora of the bay, with the exception of the birds and the higher plants. Dr. R. P. Cowles, of Johns Hopkins University, undertook the supervision of the work and personally conducted numerous cruises on the bay during 1920 to 1922. William C. Schroeder made extensive collections of fishes and obtained many data on the commercial status of the fisheries of the region. The fisheries steamer *Fish Hawk* was used in making the survey.

To supply fundamental data for the elucidation of oyster-cultural problems, especially the failure of the set, Dr. Paul S. Galtsoff, naturalist on the fisheries steamer *Albatross*, has been conducting a hydrographic and microbiologic survey of Long Island Sound and adjacent waters. The program included a series of Richter and Negretti-zambra reversing thermometer readings and Eckman current-meter readings, salinity and dissolved oxygen titrations, colorometric hydrogen-ion determinations, color and transparency determiniations, qualitative and quantitative plankton studies, and quantitative bacteriological tests. Fourteen cruises were made with the

fisheries steamer *Fish Hawk*, and observations were taken at 299 stations.

Although at the end of the fiscal year the work was not completed, Doctor Galtsoff was able to make an interesting progress report. The Sound receives salt water through both ends, but by far the most, probably nine-tenths or more, enters through the east end known as the "race." The entering sea water is diluted by the discharge from numerous rivers, particularly on the north shore, so that there is a marked decrease in salinity from the race to the head of the Sound. There is also a seasonal variation. From July to November the salinity rose and thereafter it gradually decreased. Highly polluted water enters from East River and from many industrialized and sewage-polluted streams and harbors. Accordingly, at the head of the Sound the bacterial content was high, up to 4,000 per cubic centimeter, and in certain harbors very high, indeed, up to 20,000 per cubic centimeter. However, so great is the dilution in the Sound that within 2 or 3 miles off the mouths of the worst polluted harbors the bacterial content was reduced to 100 per cubic centimeter or less. Corresponding with the evidences of pollution afforded by the bacterial examinations, the dissolved oxygen content was low at the head of the Sound and in the harbors but fairly high a short distance away from these polluted areas.

Being less affected by ocean conditions, the waters of the western part of the Sound show much higher summer temperatures than were found at the mouth. An increase also occurs in inshore waters. The hydrogen-ion studies revealed comparatively little variation from place to place, day to day, or season to season. Except for the one river, the pH values for the Sound and estuaries ranged only from 8 to 8.3. In the Housatonic River, which receives an extreme amount of acid pollution, values of 7.6 and 7.8 were recorded. Much of this information is of great interest in the study of the oyster-cultural problems of the region. When the examination of the material is completed and the work of another year added, a fine basis for the study of specific problems will have been laid.

STUDIES OF MARINE PLANKTON IN RELATION TO THE FISHERIES.

During the past year an investigation of the seasonal variation in the plankton of the Woods Hole region was carried on by Dr. Charles J. Fish, assisted by Marie D. P. Fish. The purpose of the work was to make an exhaustive investigation of the plankton, the seasonal variation of the various species, their interrelationships, and the general factors governing their distribution. As planktonic organisms form the sole food of the pelagic larval fish and are important factors, both directly and indirectly, in the diet of the adults, the results of the present investigation will serve as a basis for a future study of the factors governing the seasonal variation of both the fry and the adult fishes.

Examinations of collections taken daily were made throughout the year, together with records of temperature, salinity, and other physical governing factors. The seasonal variation of 291 species of plankton organisms, of which 36 were larval fish, were recorded. It was found that salinity has little or no effect on the plankton of the immediate region. No fresh-water streams of any size enter

Great Harbor, the salinity averaging about 31.5 throughout the year. Water temperature is the dominant factor in governing the seasonal distribution and the breeding periods of all local pelagic animals. It also determines whether oceanic species entering the region shall perish at once or live long enough to become an important factor in the local fauna.

As in the case of the bottom-living animals, the plankton of this region is made up of a complex of faunas. The region about Woods Hole forms the northern limit of many southern species, the southern limit of many northern species, and a pocket where oceanic animals blown in by strong southerly winds are deposited. The arm of Cape Cod forms a permanent northern barrier for the southern coastal plankton, but only a summer barrier for northern pelagic animals. A distinct periodicity in the occurrence of all common animals of the region is clearly noticeable. The succession of species remains the same each year, the only variation being in the time of their appearance and disappearance. The planktonic animals of the region, with one exception, may be placed in two general groups—the summer community and the winter community. The coelenterates form the exception; for the most part these have a long spring period of maximum frequency and another short one in the fall.

Three general conditions affect the appearance of the pelagic animals—winds, tides, and the food supply. Salinity forms barriers in some localities, but not at Woods Hole. Once introduced into the region, the organisms remain until the temperature becomes unfavorable or the food supply is exhausted; then they must leave or perish. Food is also an important factor in causing the disappearance of a species during a period of favorable physical conditions.

Temperature governs the breeding seasons of the plankton and benthonic animals of this region. The temperature prevailing at the time of the extrusion of the eggs is not often the important factor, for the eggs are usually thrown off as soon as ripe provided the conditions are not too unfavorable. After being deposited in the waters the existing temperature plays a controlling part in determining whether the incubation period will be long or short. The determination of an early or late breeding season depends on the temperature at some previous date when a warming or cooling of the water started the development of the sex products. These facts must be considered when interpreting the appearance of certain larvæ in the plankton.

The distribution of the plankton of the western Atlantic coast is little understood, and the number of animals new to the region taken during the past year indicates that most of the eastern Atlantic coast pelagic species will probably be found here also.

A full report of the work of the year, compiled with complete records of plankton collections by the late Vinal N. Edwards covering the years 1893-1907, inclusive, is nearly completed.

ECOLOGY OF FRESH-WATER LAKES.

Cooperation with the Wisconsin Geological and Natural History Survey in important investigations of the fundamental conditions of fish life in lakes has been continued. These studies are directed by Dr. E. A. Birge, president of the University of Wisconsin, and the work was executed by Chancey Juday and Dr. H. W. Rickett, assisted

by students from the university. The aquatic plants, the plankton, bottom fauna, and mussels of Green Lake were studied during the past year, with reference to quantity and distribution, and a report on the aquatic plants has been completed and will appear in Volume XXI of the Transactions of the Wisconsin Academy of Sciences, Arts, and Letters. Arrangements have been made for the continuance of these investigations during the fiscal year 1924.

FOULING OF SHIPS' BOTTOMS.

In September, 1922, in cooperation with the Navy Department, the bureau began an investigation of the marine growths on the bottoms of ships to determine, if possible, the conditions governing the amount and character of such growths and the possible seasonal and regional factors affecting them. The work was undertaken with a view of securing further data on the problems of preventing the attachment of the fouling organisms to ships' bottoms, as well as to determine the proper docking intervals for ships in various kinds of service. J. Paul Visscher, of Johns Hopkins University, was placed in charge of the work. Through the Navy Department he has been kept in touch with the docking of vessels in the navy yards of the Atlantic coast and has made examinations of more than 70 vessels in dry dock.

While the results so far obtained are not entirely conclusive, sufficient data have been collected to indicate that the color of the paint used is an important factor in determining the extent of fouling. In the tests made with submerged plates painted, respectively, white, black, yellow, red, green, and blue, it was found that there was much more fouling on the dark plates than on those of lighter colors. These results apparently are explained by the fact that at the time of attachment of the larvæ to the plates the organisms are negatively phototropic; that is, they tend to go away from the source of light. It would seem, therefore, that there is an important and specific relation between light and the nature and extent of the fouling of ships' bottoms.

The investigation has also indicated rather conclusively that fouling in the North Atlantic waters is caused, in the order of their importance, by barnacles, hydroids, algae, bryozoa, ascidians, and by numerous other growths of much less importance, and that most of the organisms attach while the ships are in harbor. It has been shown that vessels in commission, which never stay more than six or seven days in any port and travel between ports a considerable distance apart, do not foul seriously, at least during the period from August to March in the North Atlantic Ocean. On the other hand, it is found that vessels that lie at anchor continuously in any one port for the five or six winter months become heavily coated with hydroids but not with barnacles.

INVESTIGATIONS PERTAINING TO FISH-CULTURAL OPERATIONS.

PATHOLOGY OF FISHES.

Studies have been continued by Dr. H. S. Davis, pathologist, on *Octomitus salmonis*, an intestinal parasite of trout. In the course of these investigations visits were made to a number of hatcheries

in different parts of the country. The parasite has been found to be widely distributed and probably occurs at most of the bureau's trout hatcheries. It is strictly an intestinal parasite, usually being most abundant at the anterior end, but may be found throughout the entire length of the intestine. It occurs in two quite distinct forms that evidently represent different stages in the life cycle.

The most common form of *Octomitus* is the flagellate stage that lives in the lumen of the intestine and under certain conditions may be present in large numbers. In addition there is also an intracellular stage that is quite different in appearance and occurs in the epithelial lining of the pyloric cæca and the anterior end of the intestine. This stage first makes its appearance as a small rounded body lying in a vacuole in an epithelial cell. It grows rapidly, producing hypertrophy of the infected cell, which eventually is destroyed. After a time the parasite undergoes schizogony and the resulting schizonts invade other epithelial cells and repeat the process. On the other hand, some of the schizonts, instead of again undergoing schizogony, after a short period of growth become metamorphosed into the free-swimming flagellate. Usually both intracellular and flagellated forms are found in the same host, but under some conditions, which are not well understood, one form may greatly predominate. This is especially true of the intracellular stage, which may become very abundant without any corresponding increase in the flagellated form.

The effect of the parasite on the host varies greatly and is apparently largely dependent on local conditions. Under ordinary circumstances the injurious effects appear to be confined to the fingerlings, older fish being affected little if at all. In the young trout the parasite is often present in great numbers, the flagellates usually being more abundant than the intracellular stages. The flagellates do not ordinarily cause a severe mortality, but may seriously interfere with the proper nutrition of the host. The fish become greatly emaciated and instead of growing steadily may even lose weight for a number of weeks. The disease usually is more pronounced in the spring and apparently is associated with a slight rise in the temperature of the hatchery water. In some instances, for reasons not well understood, the intracellular stages may become very abundant, producing an inflammation of the intestine that often terminates fatally. There can be little doubt that many, if not most, of the epidemics among young fish, which occasionally break out in trout hatcheries in early spring, are due to this cause. The intracellular stages are also the cause of an excessive mortality that sometimes occurs when fish are being transported from the hatcheries. Usually there is little loss for the first 24 hours, but if the fish are held in cans for a much longer time the mortality is sometimes very high. It has been found that for some reason the intracellular stages multiply very rapidly when the fish are placed in cans, producing a fatal enteritis.

Since Octomitus is so widely distributed and occurs in the brood fish as well as fingerlings it will doubtless be very difficult, if not impossible, to eradicate it in the hatcheries. It is believed, however, that the parasite can be controlled and its injurious effects reduced to a minimum. Although it has been found in wild fish,

there is no evidence that it is very abundant or produces serious injury to the host under natural conditions. However, the unnatural conditions under which the fish are necessarily kept at the hatcheries appear to furnish an ideal opportunity for the development of the parasite, and consequently it has come to be one of the most serious pests with which the fish-culturist has to deal. Overcrowding undoubtedly is one of the conditions that favor its rapid development, and wherever the fish have been given more room there has been a noticeable improvement in their condition. It is believed that improvement in the food would also help in alleviating the injurious effects of Octomitus, and experiments have been planned with this object in view.

It has been found recently that excessive mortality, which often occurs during distribution, can be greatly reduced by keeping the fish at a much lower temperature than formerly. In fact, fish from the White Sulphur Springs (W. Va.) station, which in previous years had shown the greatest mortality, were carried at a temperature of 40° F. with very little loss.

A preliminary paper dealing with this parasite was published in the Journal of Parasitology for March, 1923.

For a number of years the Neosho station has experienced great difficulty with brood fish. The number of eggs produced often was below normal and of such poor quality that a considerable percentage failed to develop. This was most noticeable among the black bass, especially the smallmouth. Many of these fish failed to spawn, and in some of the ponds practically no fry were produced. This station was visited by the pathologist in May, and it was found that the trouble is, in all probability, due to a cestode, *Proteocephalus ambloplitis*. The plerocercoid larvæ of this tapeworm were found in large numbers in the ovaries of the smallmouth bass, while the ova had failed to develop normally. The larvæ occurred throughout the connective tissues of the viscera, but were much more abundant in the ovaries than in the other organs, and in a number of fish examined were so numerous as to effectually prevent the development of the ova. The same parasite was found in the largemouth bass, rock bass, and blue-gill sunfish, but was not as abundant in these fish as in the smallmouth. Evidently the ponds furnish exceptionally favorable conditions for the development of the parasite, which has seriously curtailed the output of the Neosho station.

A small percentage of the halibut taken on the Pacific coast are referred to as "wormy," from the fact that the flesh contains many long, white, wormlike structures that render the fish unsalable. These so-called worms are in reality hypertrophied muscle fibers that are infected with an undescribed species of myxosporidian. These parasites live only within the muscle fibers that become greatly enlarged and eventually filled with a glistening whitish mass of spores, which accounts for its wormlike appearance. A description of the parasite and its effect on the fish has been prepared for publication. This condition should not be confused with the so-called mushy halibut, which is apparently due to a small bacterialike organism that develops in the connective tissue surrounding the muscle fibers. The investigations on mushy halibut are being continued and will be reported on later.

An outbreak, in the bureau's aquarium, of the disease caused by Ichthyophthirius, provided a favorable opportunity for studies on the life history of the parasite and methods of control. These investigations were carried on by H. F. Prytherch, scientific assistant, who found that alum sulphate possesses certain advantages over chemicals previously used in the treatment of the disease. A brief bulletin on the disease is being prepared.

An outbreak of a "gas bubble" disease in developing trout at La Crosse, Wis., was investigated by the Fairport station. The disease was found to be characterized by the diffusion of yolk through the surrounding tissues and in some cases by the formation of a bubble of gas in the yolk. Since it was known that there was an excess of carbon dioxide dissolved in the water, it was suspected that this was the primary cause of the trouble. This diagnosis was borne out by the fact that elimination of the gas before the water entered the troughs caused a disappearance of the abnormal condition although the fish affected failed to recover.

At the invitation of the Minnesota State Game and Fish Commission an investigation was made of the mortality of pike perch at Cut Foot Sioux, Minn. The fish found dead had apparently been trapped some weeks before for the collection of eggs and, owing to improper handling, had been scratched and bruised, resulting in a fatal infection with Saprolegnia.

In June a severe mortality of crappie and sunfish in Lake Pokegama, Minn., was investigated by R. L. Barney, director, and H. O. Hesen, superintendent, of the Fairport station. The cause of the mortality was diagnosed as a heavy infestation of the gills by the worm Dactylogyrus with a secondary bacterial infection that usually killed the fish. This mortality at Pokegama is of particular interest in view of its regular annual occurrence in May and June for the past 15 years. Its original appearance seems to have been connected with the lowering of the water level of the lake by the blowing out of a dam, which resulted in cutting off a broad connection with Snake River. The mortality affects several species of fish, but the crappies and sunfish suffer most severely.

During June a heavy mortality of gizzard shad occurred in lakes in the suburbs of Des Moines, Iowa, and at the invitation of the State game warden an investigation was made by the Fairport station. The disease was characterized by inflation of the pectoral fins, and the study of sectioned material led to the conclusion that it was due to bacterial infection, probably by a gas-forming organism.

At the request of Representative Sweet, of Iowa, an investigation of conditions in the Iowa River was made by C. N. Blystad, of the Fairport station. A serious mortality of fishes occurred in this river during the late fall and early winter, and although fish were not dying at the time of the investigation it was possible to gather sufficient data to warrant a definite conclusion as to the cause. It was found that the mortality was due to large amounts of chemical and organic wastes allowed to pass into the stream from a sugar factory located on the river.

PHYSIOLOGY AND NUTRITION OF FISHES.

Prof. A. S. Pearse, of the University of Winconsin, and his graduate students continued their studies on the physiology and nutrition

of fishes, assisted to a limited extent by the bureau. These studies include investigations on the amount of natural food consumed, the chemical composition, the functions of the swim bladder, and the digestive enzymes of fishes. In the investigations on the chemical changes in trout and perch during growth the protein, fat, water, and ash have been determined for fish of various ages taken at intervals throughout the year. The composition of fed and starved pumpkinseeds (sunfish) has also been determined and compared with individuals caught fresh from Lake Mendota.

Studies on the function of the swim bladder have demonstrated that it is primarily a hydrostatic organ that has secondarily taken on respiratory functions. The effects of temperature and pressure on the gaseous content of the organ have been thoroughly investigated.

A study of the digestive enzymes of fish has been begun and promises to yield results of great value. Up to the present the work has been confined to pickerel, carp, and perch, but it is planned to broaden the scope of the investigation in the future.

Professor Pearse and his students have also started investigations directed at certain fundamental problems relating to the metabolism of cold-blooded vertebrates that promise to be of exceptional interest. It is planned to use turtles for these investigations, and special attention will be paid to the relation of various rations to the rate of growth; the relation of temperature to pulse, respiration, and hibernation; the basal metabolism; the amount of food required per day; the chemical composition of turtles at various seasons and ages; and the degree of activity at various temperatures.

During the latter part of the fiscal year a series of experiments for developing a more satisfactory diet for trout was inaugurated at the Manchester (Iowa) station. For many years there has been little change in the character of the food used at trout hatcheries, although in the light of the more recent knowledge of animal nutrition that has attracted much attention in late years it is evident that the standard rations are deficient in certain essential food requirements. They are especially lacking in salts and vitamines, and it is not impossible that many of the difficulties experienced at the hatcheries are in reality primarily due to an inadequate diet. For this reason it was thought advisable to undertake an extensive series of feeding experiments in the hope that it would be possible to work out a more satisfactory ration than those in use at present. Milton C. James, scientific assistant, has been assigned to this work, which was just getting under way at the end of the fiscal year.

EXPERIMENTAL WORK IN FISH CULTURE.

A number of investigations relating to the development and improvement of methods of artificial culture of some important food fishes have been conducted at the Fairport biological station. Observations on the culture of buffalofish seem to indicate that the fish will not lend itself to cultivation on a commercial scale on account of the large acreage necessary for it to attain an optimum growth. Efforts to artificially propagate the paddlefish have not yet succeeded owing to the fact that the young fish placed in one of the ponds several years ago have not yet reached the age of sexual maturity. They

will continue to be held, however, in anticipation that at some future time they may ripen and spawn. This species is of particular value commercially, and its perpetuation is a matter of concern in view of the great decrease in its numbers in recent years. Experiments in the culture of the channel catfish have been continued. Considerable light has been thrown on the natural history and essential factors for success in the pond culture of this species, and several ponds have been set aside for a practical demonstration of these experiments. At the close of the fiscal year quite a number of nests were observed, and it seems quite possible that the pond culture of this fish may be taken up on a practical basis next year. An effort at the pond culture of the hackleback sturgeon was made at the Fairport station and a large mass of data was collected, on which it is hoped to base recommendations for protective legislation for the species. The fishery for this species is of value and one that is carried on intensively because of the high prices paid for both the flesh and the eggs.

Observations on the production of the "farm pond" at Fairport have been continued with significant results. The purpose of the study of this pond production has been to obtain useful data regarding the possible value of small ponds on farms or large estates. With this end in view the pond has been handled just as one would be managed in practice; that is, the fish have not been fed but have depended on the natural "fish food," the small animals and plants that normally form the diet of food fishes and that are naturally produced in the pond.

Year.	Net production per acre.		Production of edible fish per acre.		Year.	Net production per acre.		Production of edible fish per acre.	
	Pounds.	*Ounces.*	*Pounds.*	*Ounces.*		*Pounds.*	*Ounces.*	*Pounds.*	*Ounces.*
1919	203	14	94	1	1921	374	11	92	10
1920	333	8	54	0	1922	440	14	101	11

The production of the pond has been obtained by computing the difference between the weight of the fish at the time of their introduction into the pond in spring and the weight of the same fish and their offspring as occasionally caught out during the summer or when removed from the pond at the autumn inventory. This method of computation gives the increased weight of fish in the pond due to the "turnover" of small plants and animals. The fish used (the bluegill) feeds primarily on insect larvæ, cladocerans, copepods, and plants. This annual net "turnover" of food organisms of the pond into fish flesh is here tabulated. The table includes also the weight of the fish of edible size taken from the pond.

The annual production of fish of edible size in 1919 and 1920 was based on the weight of fish removed from the pond by hook and line during the summer. In 1921 and 1922 line fishing was not carried on in the pond and the data on the production of edible-sized fish were collected when the fall inventory was made. The use of the fall measurements for this computation necessarily tends to hold down the total possible "turnover" and the total possible production of fish of edible size. The computation, however, as made for 1921 and 1922, can not be far from accurate, though the total net "turn-

over" and the production of food fish would probably have been somewhat greater had the larger fish been removed at intervals during the summers of those years.

The effort in manipulating the stock of this pond has been to so control the number of fish of different ages in it that an association might result that would give continual maximum production of fish of edible size year after year. The tendency of the manipulation for the last three years has been to decrease the number of fish constituting the spring plant, so that the small fish produced by them during the current year might not make up an undue proportion of the total annual production of fish flesh. It has been observed that too great a production of young fish in a given year prevents many of the half-grown fish from attaining edible size through too serious competition for the available food.

THE BIOLOGICAL LABORATORIES.

The biological laboratory at Woods Hole, Mass., was reopened during the summer of 1922 under the direction of Dr. R. E. Coker, then assistant in charge of the division of scientific inquiry. The laboratory was again opened in June, 1923, and was made available during the summer for investigators working on fishery problems. Doctor Coker was secured as director for the season. The policy of extending the use of the laboratory to the Marine Biological Laboratory of Woods Hole with the understanding that no charge be made by that institution for the use of the facilities provided the bureau has been continued. The laboratory has been used throughout the year by Dr. P. S. Galtsoff, naturalist of the *Albatross*, who has conducted here the laboratory work connected with the hydrographic and biological survey of Long Island Sound. Dr. Charles J. Fish and Marie D. P. Fish have also made use of the laboratory facilities in the work they have been doing on the study of the plankton and larval fishes of the Woods Hole region.

On account of the inadequate salary provision, the Beaufort Biological Laboratory has continued without a scientific director, and, with the exception of the diamond-back terrapin experiments, has remained inactive so far as the investigation of fishery problems is concerned. The facilities of the laboratory were used by several investigators during the season, among whom were Dr. L. F. Shackell, of the University of Utah; Dr. H. V. Wilson, of the University of North Carolina; and Dr. Bert Cunningham, of Trinity College, Durham, N. C. The Navy Department also made use of the laboratory in continuing its investigations on the fouling of ships' bottoms, and in October a conference was held there by the naval officers and investigators concerned. This bureau was represented at the conference by J. Paul Visscher, whose work on the fouling of ships' bottoms is referred to elsewhere in this report. The acting director has supervised the necessary repairs to buildings, sea wall, and grounds, and has carried out instructions for the conduct of the terrapin experiments, which have been intrusted largely to his care for several years past.

The work at the Key West biological station for the fiscal year has been, for the most part, of a preliminary nature. Owing to the lack of equipment and a laboratory building, together with an insufficient

personnel, little in the way of scientific work could be accomplished. Early in the year Isaac Ginsberg was appointed director of the station. His attention has been given mainly to directing much needed work in improving the grounds and the condition of the buildings, although some time has been found in which to add to the collection of Key West fishes. Observations have been made also on the natural history of the top minnow, Gambusia, in connection with the important work of distributing these fish for the purpose of controlling mosquito breeding. The station is greatly in need of a fully equipped laboratory building in which the investigation of problems relating to the important fisheries of the Gulf of Mexico and the southern Atlantic States may be carried on. At present the only space available for this work is a small room in the power house, which is also used for storing the collections and as an office.

The biological laboratory at Fairport, Iowa, has been operated during the entire year. The work has been devoted in the main to mussel and fish culture and to investigations on the natural history of some of the more important food fishes. This has been discussed in more detail in other parts of this report. The director has participated, in an advisory capacity, in various conferences with State legislative bodies with a view to the enactment of legislation for the protection of mussels. The laboratory has also been called upon frequently to render aid and advice to clubs, individuals, and State fisheries organizations in the handling of fish, in planning, building, and stocking ponds, and in pointing out the needs, care, and possible improvement of the fisheries of certain sections. Members of the staff conducted a statistical survey of the fisheries of the Illinois River for the year 1921, and a report was submitted early in the fall of 1922. The work was done in cooperation with the Illinois State Natural History Survey, the United States Public Health Service, and the Chicago Drainage District. It is the intention of the investigators to try to discover the effects of pollution and of reclamation of submerged lands along the Illinois River upon public health and recreation, agriculture, and the aquatic resources of the river. The study of the relation of the Hemiptera to the pond culture of fishes was continued by Dr. C. B. Wilson.

During the year two of the station's investigators, Dr. A. D. Howard and Barry J. Anson, resigned. The superintendent, H. L. Canfield, was transferred to the Mississippi River rescue station in August, 1922, and his place was filled by H. O. Hesen, jr.

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